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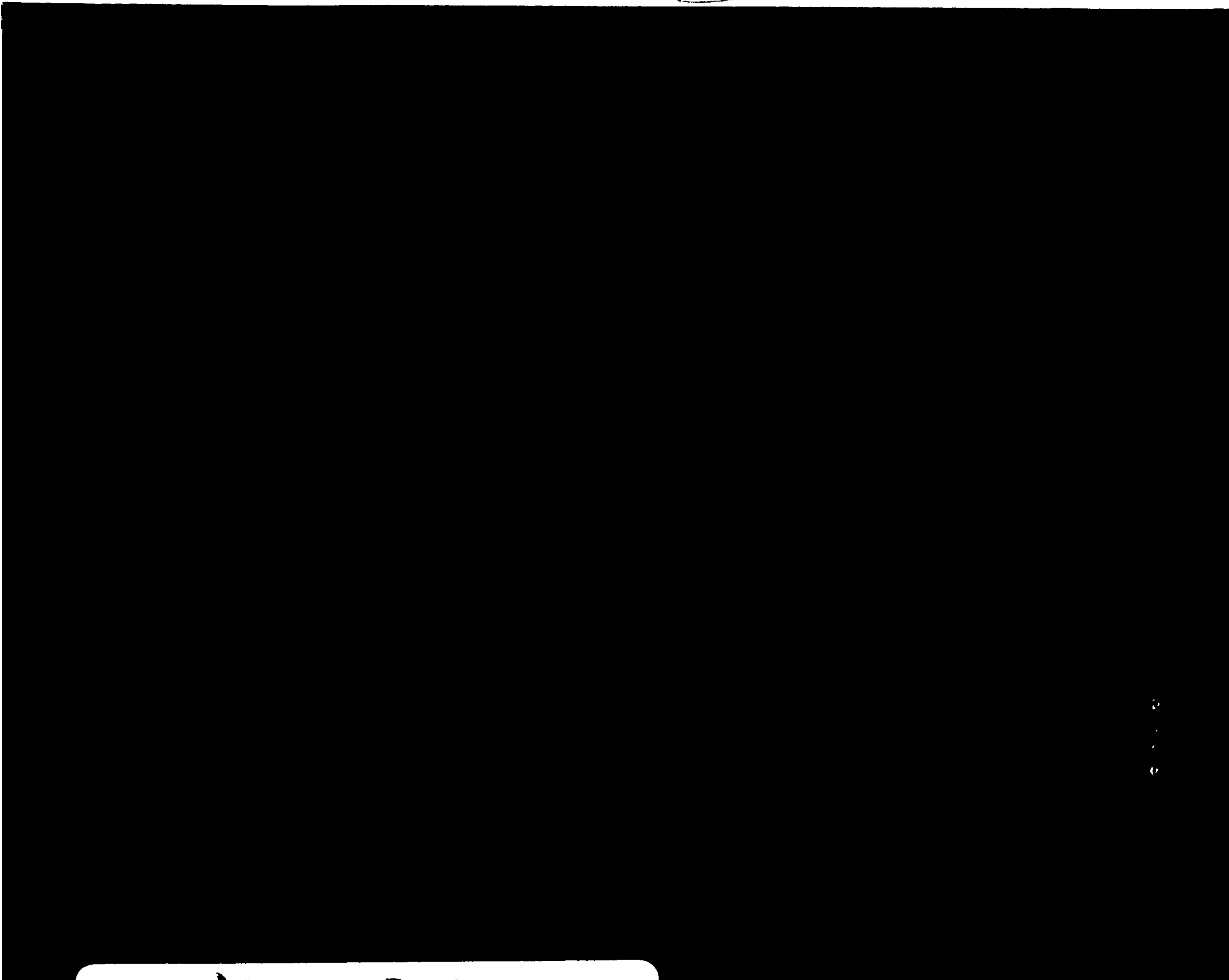

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S-IVB-502 STAGE TECHNICAL PERFORMANCE CRITERIA DOCUMENT

ORIGINAL ISSUE: DECEMBER 1967
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DOUGLAS

MISSILE & SPACE SYSTEMS DIVISION

S-IVB-502 STAGE
TECHNICAL PERFORMANCE
CRITERIA DOCUMENT

DOUGLAS REPORT DAC-56610A
ORIGINAL ISSUE: DECEMBER 1967
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PREPARED FOR:
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
UNDER NASA CONTRACT NAS7-101

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Title Page	28 March 1968
i through iv	28 March 1968
1-1	28 March 1968
2-1 and 2-3	28 March 1968
3-1 through 3-12	28 March 1968
AP1-1 and AP1-2	28 March 1968
AP2-1	28 March 1968

ABSTRACT

This Technical Performance Criteria Document contains the AS-502 mission objectives and the S-IVB-502 stage technical performance criteria which will be used to determine the Contractor's cost plus incentive fee bonus or penalty pertaining to mission accomplishment, payload capabilities and telemetry performance.

DESCRIPTORS

CPIF (cost plus incentive fee)

AS-502 Mission

S-IVB-502 stage

Preconditions of Flight

End Conditions of Flight

Telemetry Performance

Payload Capability

PREFACE

This Technical Performance Criteria Document was prepared in accordance with MSFC-DRL-021 Line Item 181 (reference 1) and supporting Data Requirements Description SE-956 (reference 1). The document contains the AS-502 mission objectives and the S-IVB-502 stage technical performance criteria which will be used to determine the Contractor's cost plus incentive bonus or penalty pertaining to mission accomplishment, payload capabilities, and telemetry performance.

PREFACE TO FIRST REVISION

Dated 28 March 1968

This report contains the second issue of the S-IVB-502 Technical Performance Criteria Document and completely supercedes the original report issued in December 1967.

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SECTION 1

INTRODUCTION

1. INTRODUCTION

This Technical Performance Criteria Document was prepared in accordance with MSFC-DRL-021 Line Item 181 (reference 1) and supporting Data Requirements Description SE-956 (reference 1). The document contains the AS-502 mission objectives and the S-IVB-502 stage technical performance criteria which will be used to determine the Contractor's cost plus incentive bonus or penalty pertaining to mission accomplishment, payload capability, and telemetry performance as defined in contract NAS7-101, supplemental agreement 1100.

The technical performance criteria includes the required preconditions of flight, end conditions of flight, mission duration, payload capability, and telemetry performance. The telemetry performance will be evaluated for two phases: (1) liftoff until first S-IVB stage ECC + 10 seconds and (2) liftoff until planned LV/SC separation.

Douglas Aircraft Company considers the SA-502 Launch Vehicle Mission Directive (reference 2) as the official document for providing identification and control of the launch vehicle mission requirements. These requirements include the primary and secondary mission objectives and are presented in section 2.

SECTION 2

MISSION OBJECTIVES

2. MISSION OBJECTIVES

Douglas Aircraft Company considers the SA-502 Launch Vehicle Mission Directive (reference 2) as the official document for providing identification and control of the launch vehicle mission requirements. The Apollo Flight Mission Assignments document (reference 3) and the Program Support Requirements document (reference 4) also define mission objectives and can be referred to for supplemental information. The mission directive states that "primary objectives are those which are mandatory and therefore, malfunctions of launch vehicle systems, ground equipment or instrumentation which would result in failure to achieve those objectives will be cause to hold or cancel the mission until the malfunction has been eliminated." The AS-502 primary objectives, as listed in the mission directive, are shown below with assigned priorities indicated to the right of each objective. For a nominal AS-502 flight, all primary launch vehicle objectives are of equal importance. The assigned priorities are intended for use in realtime mission contingency planning only.

	Primary Objectives	Assigned Priorities
a.	Demonstrate the S-IVB stage restart capability	1
b.	Demonstrate the adequacy of the S-IVB continuous vent system while in earth orbit	2
c.	Demonstrate the capability of the S-IVB auxiliary propulsion system during S-IVB powered flight and orbital coast periods to maintain attitude control and perform required maneuvers	2
d.	Demonstrate the S-IVB stage propulsion system including the propellant management systems; and determine inflight system performance parameters	2
e.	Demonstrate the S-II stage propulsion system, including programmed mixture ratio shift and the propellant management system and determine inflight performance parameters	3

Primary Objectives	Assigned Priorities
f. Demonstrate the S-IC stage propulsion system, and determine inflight system performance parameters	4
g. Demonstrate S-IC/S-II dual plane separation	5
h. Demonstrate S-II/S-IVB separation	5
i. Demonstrate the mission support capability required for launch and mission operations to high post-injection altitudes	6
j. Demonstrate structural and thermal integrity of launch vehicle throughout powered and coasting flight, and determine inflight structural loads and dynamic characteristics	6
k. Determine inflight launch vehicle internal environment	6
l. Demonstrate the launch vehicle guidance and control system during S-IC, S-II, and S-IVB powered flight, achieve guidance cutoff and evaluate system accuracy	6
m. Demonstrate launch vehicle sequencing system	6
n. Evaluate performance of the emergency detection system (EDS) in a closed-loop configuration	6
o. Demonstrate compatibility of the launch vehicle and spacecraft	6
p. Verify prelaunch and launch support equipment compatibility with launch vehicle and spacecraft systems.	7

Secondary objectives as defined in the mission directive "are those which are desirable but not mandatory. Malfunctions which may result in failure to attain these objectives may be cause to hold or cancel the mission as indicated in the launch mission rules." The secondary objectives which are listed in the mission directive are as follows:

a. Determine launch vehicle powered flight external environment

b. Determine attenuation effects of exhaust flames on RF radiating and receiving systems during main engine, retro and ullage motor firings.

SECTION 3

TECHNICAL PERFORMANCE CRITERIA

3. TECHNICAL PERFORMANCE CRITERIA

3.1 General

The Douglas Aircraft Company will be awarded a bonus if the S-IVB-502 stage successfully accomplishes the assigned flight mission. Conversely, the Contractor will be assessed a penalty if the S-IVB-502 stage fails to accomplish the assigned flight mission because of inadequate stage performance.

The S-IVB stage requirements are presented in the Contract End Item Detail Specification, No. CP209000A (reference 5).

3.2 Flight Mission Accomplishment

A mission is considered to be successfully accomplished if the S-IVB-502 stage delivers to the payload acceptable valued End Conditions of Flight (ECF) or, if having received from the lower stages and/or instrument unit (IU) inadequate Preconditions of Flight (PCF), the S-IVB stage performance is such that the ECF would have been accomplished had the PCF been adequate.

Tables 3-1 and 3-2 present the Douglas position on PCF, ECF, and their respective allowable tolerances applicable to its S-IVB-502 flight mission.

The flight time which will be used in calculating and evaluating the PCF parameters will be the time when the IU will have issued the S-II/S-IVB separation command. The flight time which will be used in calculating and evaluating the ECF trajectory parameters will be the time when the S-IVB-502 stage will have been injected into the waiting orbit, which is defined as 10 sec after the IU command signal is issued for second S-IVB J-2 engine cutoff.

The ECF attitude control parameters will be evaluated throughout S-IVB flight until S-IVB/CSM separation signal. Tolerances have been established for three specific flight phases; S-IVB powered flight, parking orbit, and waiting orbit. In the assessment of attitude control ECF, a temporary or intermittent out of tolerance condition shall not be considered an ECF violation unless the condition is caused by an S-IVB system or subsystem failure.

Table 3-3 presents the definitions used with the PCF and ECF parameters. Table 3-4 presents the equations used for calculation of ECF parameters.

3.3 Payload Capability

Payload capability for the S-IVB-502 stage is not incentivised.

3.4 Telemetry Performance Evaluation

The measurements to be evaluated for technical performance incentives are those listed in the Instrumentation Program and Components List (IP&CL) (reference 6) that are wholly on the S-IVB-502 stage and which are operative at the time the automatic launch sequence is initiated.

Measurements which achieve their intended purpose are scored as successful. Measurements which do not obtain valid data due to noise from unknown sources will be removed from the total number of measurements upon which the telemetry performance evaluation is based.

The IP&CL lists a total of 618 measurements of which 12 are not active during flight and 4 are not wholly on the S-IVB stage, leaving a total of 602 measurements to be evaluated for technical performance incentives.

The inactive measurements that will not be evaluated are listed in the following table:

Measurement No.	Measurement Title	Reason
K0141-411	Event - R/S 1 Pulse Sensor	These measurements are for checkout only and are not transmitted during flight by the S-IVB-502 stage T/M system.
K0142-411	Event - R/S 2 Pulse Sensor	
K0149-404	Event - U/R Jettison 1 Pulse Sensor	
K0150-404	Event - U/R Jettison 2 Pulse Sensor	
K0168-404	Event - Switch Selector Register Test	

K0169-404	Event - EBW Pulse Sensor OFF Indication	These measurements are for checkout only and are not transmitted during flight by the S-IVB-502 stage T/M system.
K0176-404	Event - Ullage Rocket Ignition Pulse Sensor 1 Indication	
K0177-404	Event - Ullage Rocket Ignition Pulse Sensor 2 Indication	
D0545-407	Press - Common Bulkhead Int-H/W	These measurements are landline for prelaunch requirements and are not transmitted during flight by the S-IVB-502 stage T/M system.
D0576-408	Press - Fuel Tank Ullage Umb-H/W	
D0577-406	Press - Oxid Tank Ullage Umb-H/W	
K0152-404	Event - Rate Gyro Wheel Speed OK Indications	Rate Gyro is not installed.

The measurements not wholly on the S-IVB stage are the following:

D0153-423	Press - Chamb Retro Rkt Pos IV-I	Transmitted by S-II stage T/M
D0154-421	Press - Chamb Retro Rkt Pos II-III	
D0155-420	Press - Chamb Retro Rkt Pos I-II	
D0156-422	Press - Chamb Retro Rkt Pos III-IV	

3.4.1 Performance Baseline Determination

Douglas Aircraft Company will utilize the following procedure to establish the operative and non-operative telemetry measurements at the initiation of the last automatic sequence prior to liftoff. This information will be used as the baseline for subsequent calculation of the telemetry performance incentive.

Prior to resuming the count for T -0 day, the DAC/FTC Project Engineer will contact MSFC/S-IVB Project Office to review the inoperative measurements, their failure mode, and their effect on launch and/or mission.

Continual surveillance for inoperative measurements will be made by Contractor personnel in the blockhouse and the Central Instrumentation Facility (CIF) during T -0 day. MSFC will be periodically contacted by the DAC/FTC Project Engineer up until approximately T -15 min to report any additional inoperative measurements detected either by the Launch Control Center or CIF personnel. Measurement scans will be made periodically by dialing up measurements in the CIF and the Saturn V Measuring Station. MSFC will in most instances be able to verify inoperative measurements by viewing the same data as it is being transmitted to the Huntsville Operations Support Center (HOSC) from the CIF.

The Douglas S-IVB Project Engineer will dictate a Memo of Agreement to document those measurements which the Contractor declares inoperative prior to initiation of the automatic launch sequence.

3.4.2 Performance Evaluation Period

The expected duration of the telemetry performance evaluation will be as follows:

a. Phase I

From AS-502 launch vehicle liftoff until first S-IVB stage ECC +10 sec.

b. Phase II

From AS-502 launch vehicle liftoff until planned LV/SC separation, as defined in the Definition of Saturn SA-502 Flight Sequence Program, No. 40M33622 (reference 7).

3.4.3 Command Requirements

In order to ensure the required transmission of data from the S-IVB stage telemetry system, the following commands must be received from the IU as scheduled in the sequence of events:

Special calibration relays ON	PCM transmitter ON
Special calibration relays OFF	PCM transmitter OFF
Regular calibration relays ON	Slow record ON
Regular calibration relays OFF	Slow record OFF

FM transmitters ON	Fast record ON
FM transmitters OFF	Fast record OFF
FM SCO assemblies ON	Recorder playback ON
FM SCO assemblies OFF	Recorder playback OFF
SSB/FM transmitter ON	Emergency playback ON
SSB/FM transmitter OFF	Emergency playback OFF

TABLE 3-1 (Sheet 1 of 2)
DOUGLAS POSITION, S-IVB-502 PCF AND ASSOCIATED TOLERANCES
(S-II/S-IVB SEPARATION COMMAND)

PARAMETERS	UNITS	NOMINAL	TOLERANCES	EVALUATION** INACCURACY	TOTAL ENVELOPE
*Range	km	+1,505.4	+54.6 -70.3	±0.8	+55.4 -71.1
*Crossrange (see note 1)	km	+40.8	+2.7 -3.0	±0.8	+3.5 -3.8
*Altitude	km	+188.8	+2.6 -2.6	±0.8	+3.4 -3.4
Velocity Vector Magnitude	m/sec	+6,834.4	+49.4 -63.1	±3.0	+52.4 -66.1
Velocity Vector Direction (Path Angle from Local Horizontal)	deg	+0.78	+0.33 -0.29	±0.05	+0.38 -0.34
Pitch Attitude (see note 2)	deg	-96.3	+4.0 -4.0	±1.0	+5.0 -5.0
Pitch Rate	deg/sec	0.0	+1.0 -1.0	±0.5	+1.5 -1.5
Yaw Attitude (see note 3)	deg	+0.3	+2.8 -2.7	±1.0	+3.8 -3.7
Yaw Rate	deg/sec	0.0	+1.0 -1.0	±0.5	+1.5 -1.5
Roll Attitude	deg	0.0	+3.0 -3.0	±1.0	+4.0 -4.0
Roll Rate	deg/sec	0.0	+1.0 -1.0	±0.5	+1.5 -1.5

TABLE 3-1 (Sheet 2 of 2)
DOUGLAS POSITION, S-IVB-502 PCF AND ASSOCIATED TOLERANCES
(S-II/S-IVB SEPARATION COMMAND)

*Earth fixed.

**Assuming only radar tracking available for trajectory parameters.

NOTES:

1. Crossrange is measured laterally, along a line normal to the plane containing the flight azimuth, the launch pad plumbline, and the earth center. Positive is to the right, looking along the azimuth direction.

2. Pitch attitude is measured negatively nose downrange from the launch vertical, in the pitch plane.

3. Yaw attitude is measured positive nose to the right in the yaw plane, as seen looking forward with position one down.

TABLE 3-2 (Sheet 1 of 2)
DOUGLAS POSITION, S-IVB-502 ECF AND ASSOCIATED TOLERANCES
(WAITING ORBIT INJECTION)

A. S-IVB TRAJECTORY ECF PARAMETERS

PARAMETERS	UNITS	NOMINAL	TOLERANCES	LH2 UNCERTAINTY	EVALUATION* INACCURACY	TOTAL ENVELOPE
Inclination	deg	+32.485	+0.033 -0.034	+0.000 -0.002	±0.016	+0.049 -0.052
Node	deg	+122.490	+0.190 -0.191	+0.000 -0.004	±0.030	+0.220 -0.225
C_3	m^2/sec^2	-1,491,156	+32,661 -31,356	+7,664 -75,000	+85,350 -87,323	+125,675 -193,679
Eccentricity		+0.97532	+0.00054 -0.00052	+0.00012 -0.00140	±0.00140	+0.00206 -0.00332

B. S-IVB ECF ATTITUDE CONTROL PARAMETERS**

PARAMETERS	UNITS	TOLERANCES	EVALUATION INACCURACY	TOTAL ENVELOPE
S-IVB Burn Phase				
Pitch or Yaw Attitude Error	deg	±5.0	±1.0	±6.0
Roll Attitude Error	deg	±12.5	±1.0	±13.5
Pitch or Yaw Rate	deg/sec	±2.5	±0.5	±3.0
Roll Rate	deg/sec	±1.0	±0.5	±1.5

TABLE 3-2 (Sheet 2 of 2)
DOUGLAS POSITION, S-IVB-502 ECF AND ASSOCIATED TOLERANCES
(WAITING ORBIT INJECTION)

PARAMETERS	UNITS	TOLERANCES	EVALUATION INACCURACY	TOTAL ENVELOPE
Parking Orbit (to restart)				
Pitch or Yaw Attitude Error	deg	±3.0	±1.0	±4.0
Roll Attitude Error	deg	±12.5	±1.0	±13.5
Pitch or Yaw Rate	deg/sec	±0.7	±0.5	±1.2
Roll Rate	deg/sec	±1.0	±0.5	±1.5
Waiting Orbit (to CSM separation signal)				
Pitch or Yaw Attitude Error	deg	±3.0	±1.0	±4.0
Roll Attitude Error	deg	±12.5	±1.0	±13.5
Pitch or Yaw Rate	deg/sec	±1.6	±0.5	±2.1
Roll Rate	deg/sec	±1.6	±0.5	±2.1

*Assuming only radar tracking available for trajectory parameters.

**Attitude errors during parking and waiting orbit exclude normal transients and maneuvers; all rates apply to rigid body response (structural dynamics effects are excluded).

TABLE 3-3 (Sheet 1 of 2)
PCF AND ECF PARAMETER DEFINITION

PARAMETER	DEFINITION
Range	Spherical earth ground range. Based on the spherical earth range angle and the average earth radius.
Cross-range	Component of vehicle position as measured laterally, along a line normal to the plane containing the flight azimuth, the launch pad plumbline, and the earth center. Positive is to the right, looking along the azimuth direction.
Altitude	Distance between the spheroid's surface and vehicle measured along the normal to the earth's surface, positive up.
Velocity vector magnitude	Measured with respect to non-rotating space fixed reference system.
Velocity vector direction	Angle between inertial velocity vector and a plane perpendicular to the instantaneous earth radius vector.
Pitch attitude	Inertial Euler angle measured between the platform "P" coordinate system and the vehicle fixed "M" system. The rotation order is pitch, yaw, roll. Pitch attitude is measured negatively nose downrange from the launch vertical, in the pitch plane.
Pitch rate	Angular velocity about vehicle pitch axis, positive nose up.
Pitch attitude error	Commanded pitch attitude minus the vehicle pitch attitude measured in vehicle coordinates.
Yaw attitude	Inertial Euler angle measured between the platform "P" coordinate system, and the vehicle fixed "M" system. The rotation order is pitch, yaw, roll. Yaw attitude is measured positive nose to the right in the yaw plane, as seen looking forward with position one down.
Yaw rate	Angular velocity about vehicle yaw axis, positive nose right.

TABLE 3-3 (Sheet 2 of 2)
PCF AND ECF PARAMETER DEFINITION

PARAMETER	DEFINITION
Yaw attitude error	Commanded yaw attitude minus the vehicle yaw attitude measured in vehicle coordinates.
Roll attitude	Inertial Euler angle measured between the platform "P" coordinate system and the vehicle fixed "M" system. The rotation order is pitch, yaw, roll. Roll attitude is measured positive in the roll plane in a clockwise direction as seen looking forward.
Roll rate	Angular velocity about vehicle roll axis, positive clockwise looking forward.
Roll attitude error	Commanded roll attitude minus the vehicle roll attitude measured in vehicle coordinates.
Inclination (i) Eccentricity (e) Longitude of Descending Node (θ_N)	Elements of waiting orbit. Longitude of descending node is measured in the earth's equatorial plane relative to the longitude of the launch site at Guidance Reference Release, positive east. Calculated as shown in table 3-4.
Energy (C_3)	Energy of waiting orbit. Equals twice the total waiting orbit vis-viva energy. Calculated as shown in table 3-4.

TABLE 3-4
EQUATIONS FOR C_3, INCLINATION, NODE PARAMETER AND ECCENTRICITY

The equations used to calculate eccentricity, C_3, node, and inclination for the AS-502 S-IVB ECF's are listed below. Position and velocity data used to calculate the sub-equations of P and γ are in the Apollo Coordinate System Standard 13.

$$\text{Eccentricity} = \sqrt{1 - \frac{(2\mu - RV^2)\ (1 - \sin^2 \gamma)\ RV^2}{\mu^2}}$$

$$C_3 = V^2 - \frac{2\ \mu}{R}$$

$$\text{Node} = \cos^{-1} - \left(\frac{P_u}{P_{uv}}\right) = 90° + \sin^{-1} \left(\frac{P_u}{P_{uv}}\right)$$

$$\text{Inclination} = \cos^{-1}\left(\frac{P_w}{P}\right)$$

Using $\bar{P} = \bar{V} \times \bar{R}$

$$P_u = P_3 \sin A_z + P_2 \cos A_z$$

$$P_v = - P_3 \sin \phi_L \cos A_z + P_1 \cos \phi_L + P_2 \sin \phi_L \sin A_z$$

$$P_w = - P_3 \cos \phi_L \operatorname{cox} A_z - P_1 \sin \phi_L + P_2 \cos \phi_L \sin A_z$$

$$P_{uv} = \sqrt{{P_u}^2 + {P_v}^2}$$

$$\gamma = \sin^{-1} \left(\frac{X\dot{X} + Y\dot{Y} + Z\dot{Z}}{RV}\right)$$

$$\mu = 3.986032E14\ m^3/sec^2$$

$$A_z = 72 \text{ deg}$$

$$\phi_L = 28.60842 \text{ deg}$$

APPENDIX 1

GLOSSARY AND ABBREVIATIONS

TABLE AP 1-1 (Sheet 1 of 2)
GLOSSARY AND ABBREVIATIONS

ABBREVIATION	TERM	DEFINITION
AS	--	Apollo Saturn
CPIF	--	Cost plus incentive fee
CIF	--	Central Instrumentation Facility
CSM	--	Command service module
DAC	--	Douglas Aircraft Company
DAC/FTC	--	Douglas Aircraft Company, Florida Test Center
deg	--	Degree
EBW	--	Exploding bridgewire
ECC	--	Engine Cutoff Command
ECF	--	End Conditions of Flight
EDS	--	Emergency Detection System
FM	--	Frequency modulation
HOSC	--	Huntsville Operations Support Center
H/W	--	Hardwire
IP&CL	--	Instrument Program and Components List
IU	--	Instrument Unit
km	--	Kilometers
LV	--	Launch vehicle
MSFC	--	Marshall Space Flight Center
NASA	--	National Aeronautics and Space Administration
PCF	--	Preconditions of Flight
PCM	--	Pulse code modulation

TABLE AP 1-1 (Sheet 2 of 2)
GLOSSARY AND ABBREVIATIONS

ABBREVIATION	TERM	DEFINITION
RF	--	Radio frequency
R/S	--	Range safety
SA	--	Saturn
SC	Spacecraft	Includes Apollo command and service module and LM adapter
SCO	--	Sub-carrier oscillator
S-II	--	Second stage of the Saturn V (500) series of vehicles
S-IC	--	First stage of the Saturn V (500) series of vehicles
S-IVB	--	Second stage of the Saturn IB (200) series of vehicles and third stage of the Saturn V (500) series of vehicles
SSB	--	Single sideband
T/M	--	Telemetry
U/R	--	Ullage rocket

APPENDIX 2

REFERENCES

2. REFERENCES

The following listed documents are referenced in the text:

(1) NAS7-101 Contract Data Requirements Saturn S-IVB Stage and GSE, (MSFC-DRL-021) Line Item 181, Revision A, dated February 1, 1968.

(2) SA-502 Launch Vehicle Mission Directive, (prepared by Saturn V Test Office), Marshall Space Flight Center, Huntsville, Alabama, Revision A, Change I, dated December 27, 1967.

(3) Apollo Flight Mission Assignments (U), (prepared by Office of Manned Space Flight, Apollo Program), M-D MA500-11, SE010-000-1, Washington, D.C., dated January, 1968.

(4) Apollo Saturn V Program Support Requirements, (prepared by Office of Manned Space Flight, Apollo Program), Z1NPX, Revision 2, Washington, D.C., dated December 28, 1967.

(5) Contract End Item Detail Specification (Prime Equipment) Performance Design Requirements, CEI No. 209000A, S-IVB Stages 501 through 506, Douglas Aircraft Company, Huntington Beach, California, dated March 9, 1967.

(6) Instrumentation Program and Components List S-IVB-502, 1B43567AL, Douglas Aircraft Company, Huntington Beach, California, Revision AL, dated February 21, 1968.

(7) Definition of Saturn SA-502 Flight Sequence Program, Interface Control Document No. 40M33622C (prepared by Airborne Electrical Systems Branch, Astrionics Laboratory) Marshall Space Flight Center, Huntsville, Alabama, dated May 13, 1966.

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